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DESIGN AND FABRICATION OF OVERHEAD TRAVELLING CARGO HANDLING MACHINE FOR WAREHOUSE

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ABSTRACT

Warehouses are large plain and commercial buildings used for storage of goods by manufacturers, importers, exporters, wholesalers, transport businesses, customs department. Earlier days unloading, stacking and loading operations were being done manually, which requires a huge number of porters to handle the material. For the last few decades, people are using fork lifts, conveyors and Hook Cranes to perform the unloading, staking and loading operations. Conventionally, these forklifts are powered by I. C. Engines which emit exhaust gases inside the warehouses. So, in order to overcome such drawbacks, D. C. motor driven forklifts were developed. But they cannot be used for heavy loads. They also require large turning radius / moving space. The technical solution that is deemed feasible and capable of addressing the above mentioned issues is an electrically operated overhead travelling cargo handling machine which reduces the turning radius and increases the storage area. In this overhead travelling forklift, we have a column to which the fork is attached. This column can move along the long travel and cross travel with ease. In this we use a bevel gear which helps us in slewing of fork. The fork lift with the help of AC motor instead of DC motors and I. C engines, which require refueling or recharging time. As a part of our project dissertation, we are making "Overhead travelling cargo handling machine for warehouses" which might be helpful in the reduction of exhaust emissions from forklift exhaust in warehouse as it operates with electric energy. The main objective of this project work is to study the physical properties, optimum parameters of the process and the working rate of existing techniques of material handling (Cargo handling) and develop a design approach to provide a better working environment to the workers working in warehouses and subsequently increase the storage space.

KEYWORDS: I. C Engines, Warehouses, Cargo, Material Handling, Design Approach & Material

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Original Article

INTRODUCTION

Material handling is defined as the movement of material of any form (raw, finished, packaged, solid, liquid, gas, light and heavy) from one location to another location either in the restricted path by manual or mechanical aids. The movement may be horizontal, vertical or may be a combination of both. Material handling plays an important role in manufacturing and logistics, which together represent over 20% of the production facility's economy. Almost every item of physical commerce was transported on a conveyor or lift truck or other type of material handling equipment in manufacturing plants, warehouses, and retail stores. The demand of construction and material equipment is correlated with the growth of Infrastructure sector. India still needs to develop it in a big way. There is substantial scope for the growth of the infrastructure sector viz., Roads, Steel, Coal, Cement, Power etc. Also, with increased need of mechanization and shrinking timelines of infrastructures projects, the demand for equipments should see a definitive upward trend. The demand is largely from F&B, retail and automobile sectors. Palletisation and containerization are also expected to increase demand. The Material

handling is a necessary and significant component of any productive activity. It is something that goes on in every plant all the time. Material handling means providing the right amount of the right material, in the right condition, at the right place, at the right time, in the right position and for the right cost, by using the right method. It is simply picking up, moving, and lying down of materials through manufacture. It applies to the movement of raw materials, parts in process, finished goods, packing materials, and disposal of scraps. In general, hundreds and thousands tons of materials are handled daily requiring the use of large amount of manpower while the movement of materials takes place from one processing area to another or from one department to another department of the plant. The cost of material handling contributes significantly to the total cost of manufacturing.

Table

Specifications	Description
Material handling productivity	Should be able to achieve double the current productivity
System affordability	Should be cheap and affordable by Warehouse operators
Operation of Machine	Eco-friendly and easy to use
Assembly of machine	Ease of assembly
Trouble Shooting	Maintenance of the machine should not be complicated
Components	Should be Sourced locally

The Main Objectives of the Research are

To gather the information for developing a product for cargo handling process in warehouses. This includes study of physical properties of present method, optimum parameters of the process and its working rate. To develop a design methodology to create an eco-friendly work environment for the workers in the warehouses. To design and develop an overhead travelling cargo handling machine that can complete the task by without producing any emissions in the warehouse

DESIGN OF OVERHEAD TRAVELLING CARGO HANDLING MACHINE

The functional requirement is a resource for what the product must be able to accomplish when it is completed. It generally refers to the broad needs and wants of the entity as well as the users of the product. They represent an overall statement of working tools and guidance throughout the design process. There are two sources of information for functional requirements. An external source includes customer specifications, industry standards, and product feedback; and an internal source, includes marketing, sales requirements, and product development requirements. For this study, external source, i.e., the plant survey provided the input for functional requirements specifications. The system requirements are presented in Table: 3.1

Design for Fork

The forks are the fingers of the forklift which lifts the material to be handed. The design of fork is as follows:

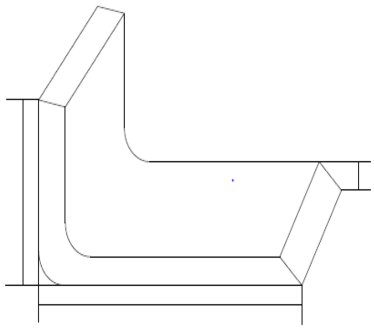
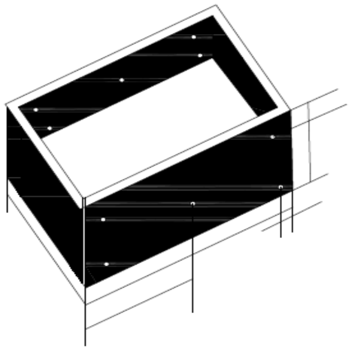
Mass of forks = volume of forks (V) x density

Since the material used is mild steel kg/m-s

Volume of forks (V) = Area x thickness

Area = 2 (170 x 16) = 6,440 mm^2

Volume of forks = 5,440 x 3 = 16,200 mm^3

Isometric View of Forks Isometric View of Fork Carrier

Mass of the forks = 16,200 x 7650 x 10^{-9} Kg = 0.123 Kg

Thus the estimated theoretical mass of the forks is found to be 0.123 Kg.

Design for Fork Carrier

The fork carrier is made by fabricating the mild steel plates. This is having a density of Kg/m-s

Mass of the Fork carrier = volume (V) x density

Since the material used is mild steel =7650 Kg/m-s

Volume = Areax thickness (t)

We know that thickness of material t = 3mm

Area of the fork carrier = 2 (38x85) + 2 (110x39) = 6460+8360 = 4820 mm^2

Volume of fork carrier = 14820 x 3 = 44,460 mm^3

Mass of the Fork carrier = 44,460 x 7650 x 10^{-9} Kg = 0.3401 Kg

Thus the estimated theoretical mass of the fork carrier is found to be 0.3401 Kg

Design for Column

Mass of the column = volume x density

Volume = Area x thickness (t)

Area of column = 2 (70x355) + 2 (69x70) = 49,700 + 9,660 = 59,360 mm^2

Volume (V) = 59,360 x 3 = 1, 78, 080 mm^3

Gear Ratio we have chosen is 1.16

With this gear ratio

The speed achieved = 3.5/1.6 = 2.33 RPM = $2\text{x} \frac{(3.141) \text{ x } (2.33) \text{ x } (7.81)}{60}$ =1.90 W

Speed of slewing required = 2 RPM

The speed of motor available in market = 3.5 RPM

The speed achieved from the motor is greater than the required speed

Hence the selected motor & gear ratio are satisfied.

Mass of the column = 1, 78,080 x 7650 x 10^{-9} Kg = 1.140 Kg

Therefore the theoretical mass of the column is estimated to be 1.140 Kg.

Design for Trolley

The trolley is made of mild steel which is having a density of Kg/m-s

Mass of trolley = volume (V) x density

Volume = Area x thickness (t)

Area = (145 x 145) + 2(64x145) = 21025 + 18560 = 39585 mm^2

Volume of trolley (V) = 89585 x 3 = 118756 mm^3

Mass of the trolley = 118756 x 7650 x 10^{-9} Kg = 0.908 Kg

Therefore the theoretical mass of the trolley is 0.908 Kg

Design for Long Travel Girder

The long travel girders are made of Galvanized Iron sheet metal which has a thickness of 1mm. whose density is = 7650 Kg/m-s

Mass of long travel track = volume (V) x density

Volume = Area x Thickness (t)

Area = 2 (860 x 16) = 2 (13760) = 29520 mm^2

Volume (V) = 27520 x 1 = 27520 mm^3

Mass of long travel track = 27520 x 7600 x 10^{-7} kg = 0.210 Kg.

Design for Cross Travel Girder

The Cross travel Girder is made of Galvanized Iron sheet of having thickness 1mm which will be having a density of Kg/m-s

Mass of cross travel track = Volume (V) x density (ρ)

Volume = Area x thickness (t)

Area = 2 (800 x 16) = 25600 mm^2

Volume (V) = 25600 x 1 = 25600 mm^3

Mass of cross travel track = 25600 x 7650 x 10^{-9}kg = 0.201 Kg.

Thus the estimated mass of the Cross Travel Girder is found to be 0.201 Kg.

Design for Bevel Gear

POWER =1.90 W

RPM (n) =3.5

GEAR RATIO (i) =1:1.5

MATERIAL FOR GEAR AND PINION = EN 8 or C45 STEEL

LIFE = 8000 hrs

NO. OF TEETH ON PINION (Z_1) =16

NO. OF TEETH ON GEAR (Z_2) =1

Nominal Twisting Moment Transmitted by Pinion (M_t)

$$M_t = \frac{p*60}{2*\pi n}$$

$$.M_t = \frac{1.90*60}{2\pi*3.5}$$

.M_t= 5.183 N-mm

Design Twisting Moment ([M_t])

[M_t]= M_tk.k_d

[M_t] = 5.183 * 1.5

[M_t] = 7.775 N-m

Cone Distance

$$\mathbf{R} \geq \varphi_y\sqrt{i^2+1}\sqrt[3]{\left\{\frac{0.72}{(\varphi_y-0.5)[\sigma_c]}\right\}^2\frac{E.M_t}{i}}$$

.φ_y = Ratio of cone distance to face width ($\varphi_y = \frac{R}{b}$)

.[σ_c] = design compressive stress

E = Young's modulus (2.15*10^5 $N - mm^2$)

I = Gear ratio

Using design data hand book:-

Type of gear transmission (for bevel gear) is

Housed in roller bearing i=1 to 4 &φ_y = $\frac{R}{b}$ = 3

$$.\mathbf{R} \geq 3\sqrt{\left(\frac{1}{1.6}\right)^2+1}\sqrt[3]{\left\{\frac{0.72}{(3-0.5)[500]}\right\}^2\frac{2.15*10^5*[7.775]}{\left(\frac{1}{1.6}\right)}}$$

.R≥ 3.365mm

Average Module (m_{av})

$$.m_{av} \geq 1.26 \sqrt[3]{\frac{[M_t]}{y_v * [\sigma_b] \varphi_m Z_1}}$$ (Assume $\varphi_m = \frac{b}{m_{av}} = 10$)

$$.m_{av} \geq 1.26 \sqrt[3]{\frac{7.775}{y_v * 140 * 10 * 16}}$$

So, to get y_v we need to calculate Z_v

$Z_{V=}$ Virtual number of teeth

y_v = form factor for virtual number of teeth

$$Z_V = \frac{z_1}{cos\delta_1}$$

We know that $\delta_1 + \delta_2 = 90^{\circ}$ (δ_1 = pitch angle for pinion & δ_2 = Pitch angle of gear)

Tan $\delta_2 = i$

$$\delta_2 = \tan^{-1}\left(\frac{1}{1.6}\right)$$

$$\delta_2 = 32.005^{\circ}$$

then

$$\delta_1 = 90^{\circ} - 32.005^{\circ}$$

$$\delta_1 = 57.995^{\circ}$$

Virtual Number of Teeth

$$\mathbf{Z_{V_1}} = \frac{\mathbf{z_1}}{\mathbf{cos\delta_1}}$$

$$= \frac{16}{cos(57.995)}$$

= 30.1896 mm

($\therefore z_1$ = Number of teeth of pinion &

z_2 = Number of teeth of gear)

$$\boldsymbol{Z_{V_2}} = \frac{\boldsymbol{z_2}}{\boldsymbol{cos\delta_2}}$$

$$= \frac{10}{cos(32.005)}$$

= 11.802 mm

Then using form factor, y for $\alpha = 20^{\circ}$ & $f^* = 1$ table from hand book

$y_v = 0.458$

Now,

$$m_{a_v} = 1.26 * \sqrt[3]{\frac{7.775*10^3}{0.458*140*10*16}}$$

$$.m_{a_v} = 1.1487 \text{ mm}$$

Transverse Module (m_t)

$$\mathbf{m_t} = \mathbf{m_{a_v}}\left\{\frac{\varphi_y}{\varphi_y - 0.5}\right\}$$

$$= 1.1487\left\{\frac{3}{3-0.5}\right\}$$

$$= 1.379 \text{ mm}$$

Cone Distance Related with Number of Teeth

$$\mathbf{R} = 0.5 m_t z_1 \sqrt{i^2 + 1}$$

$$R = 0.5*1.379*16*\sqrt{(\frac{1}{1.6})^2 + 1}$$

$$R = 13.009 \text{ mm}$$

PITCH CIRCLE DIAMETER OF GEAR AT ITS OUTER PORTION

$$d_1 = m_t * Z_1$$

$$d_2 = 1.379 * 16$$

$$d_1 = 22.064 \text{ mm}$$

Pitch Circle Diameter of Pinion at its Outer Portion

$$d_2 = m_t * z_2$$

$$d_2 = 1.379 * 10$$

$$d_2 = 13.79 \text{ mm}$$

Induced Compressive Stress on Gear Tooth:

$$\sigma_c = \frac{0.72}{(R-0.5b)}\sqrt{\frac{(i^2+1)^{3/2}}{ib}E.[M_t]} \le [\sigma_c]$$

$$(\therefore \varphi_y = \frac{R}{b} = \frac{cone\ distance}{face\ width\ of\ tooth})$$

$$b = \frac{R}{\varphi_y} = \frac{13.009}{3}$$

$$b = 4.336$$

$$\sigma_c = \frac{0.72}{(13.009-0.5*1.336)}\sqrt{\left\{\frac{((\frac{1}{1.6})^2+1)^{\frac{3}{2}}}{(\frac{1}{1.6})*4.336}\right\} * 2.15 \times 10^5 * 7.775}$$

$$\sigma_c = 66.796 \text{ N/mm}^2$$

Induced Bending Stress on Gear Tooth

$$\sigma_b = \frac{R\sqrt{i^2+1} \times [M_t]}{(R-0.5b)^2 \times b.m_t.y_v.\cos(\alpha)} \leq [\sigma_c]$$

(Assume$\alpha = 20^\circ$)

$$\sigma_b = \frac{13.009\sqrt{(\frac{1}{1.6})^2+1}\,(7.775*10^3)}{(13.009-0.5*4.336)^2*4.336*1.379*0.458*\cos(20)}$$

$\sigma_b = 39.4371$ N/m^2

Tip Circle Diameter

$$d_{a_1} = m_t(z_1 + 2\cos\delta_1)$$

=1.379(16+2cos (57.995))

$d_{a_1} = 23.525$ mm

$$d_{a_2} = m_t(z_2 + 2\cos\delta_2)$$

$= 1.379(10 + 2\cos(32.005))$

$d_{a_2} = 16.128$ mm

Addendum

$$h_a = 1 * m_t$$

=1*1.379

$h_a = 1.379$

Dedendum

$$h_f = 1.124 * m_t$$

= 1.124*1.379

$h_f = 1.5499$.

As the working medium here is steel C-45.Thus a Bevel gear is designed for our requirement in the prototype. But we are using EN-8 material instead of C-45 as it is readily available according to our requirement.

Design Power and Load Calculations

Mass of the Fork carrier = 0.8401 + 0.123= 0.431 Kg.

Expected lifting mass = 1.50 Kg

Total mass to be lifted = 1.50 + 0.431= 1.9631 Kg

Diameter of the pulley = 15 / 1000m = 0.015m

Force = F x mg. = 1.9631 x 9.81= 19.35 m/s

Let us consider the speed of pulley = 3.5 RPM

Torque of the pulley = FxR= 19.35 x 0.0075= 0.144 N-M

= 2x (77) x (3.5) x (0.0144) / 60= 2.3.141 x 3.5 x 0.144 / 60= 0.052W

Expected lift = 100 mm / min

N = 1.50 / □□x15 = 3.18 RPM

The speed of the motor we considered is 3.5 RPM

Mass of the column = 1.140 Kg

Expected lift mass = Column mass+ 1.9631= 1.140 + 1.9631= 3.103 Kg

Total mass to be lifted = 1.40 + 3.103= 4.5031 Kg

Force F = mg= 4.5031 x 9.81= 44.17 m/s

Radius of Rotation = 177mm = 0.77M

Slewing Torque T = F X R= 44.19 x 0.177= 7.81 N.M.

Gear ratio we have chosen is 1:1.6 with this gear ratio

The speed achieved = 3.5/1.5 = 2.33RPM

Power required for slewing motion

P =2πNT/60 =2 x (3.141) x (2.33) x (7.81) /60=1.90W

Speed of the slewing required = 2RPM

The speed of the motor available in market =3.5RPM

Therefore the speed achieved from the motor is greater than the required speed

Hence the selected motor & gear ratio are satisfied.

FABRICATION OF OVERHEAD TRAVELLING CARGO HANDLING MACHINE

Metal fabrication is the building of metal structures by cutting, bending and assembling processes. It is a value added process that involves the construction of machines and structures from various raw materials. A fabrication shop will bid on a job, usually based on the engineering drawings, and if awarded the contract will build the product. Large fabrication shops will employ a multitude of value added processes in one plant or facility including welding, cutting, forming and machining. Metal fabrication jobs usually starts with shop drawing including precise measurements then move to fabrication stage and finally to the installation of the final project. After the design for each component, its drawings have been developed. With those drawings, the components were fabricated using different processes which are discussed as follows.

Forks

A fork is the main component of the forklift which is to be designed and manufactured carefully. For making a

pair of forks, a mild sheet which is galvanized is considered. A development drawing was developed for the fork. Referring to the diagram the 3mm thick sheet of was taken and cut to the **Schematic view of finished forks**

Required dimensions by using laser cutting technique. Then the metal is bent to form L-shaped forks. A figure the finished forks.

Fabrication of Fork Carrier

For fabricating of a fork carrier, a mild steel sheet which is galvanized is considered. Then the mild steel sheet is cut into plates by using laser cutting as the sheet is 3mm thick. Then, using arc welding the metal sheet was finally joined to form the shape of a fork carrier.

Schematic View of a Fork Carrier

Holes with 3 mm diameter were drilled in order to place the shaft for placing wooden idlers. These wooden idlers roll along the length of the column while operating. Then the forks are welded to the carrier by using arc welding technique. The entire arrangement is shown in figure 4.2

Fabrication of Column

For providing the support for the fork carrier and the load to be lifted by the forklift, a column is provided in the machine which supports the fork carrier throughout the operational limit. For this, a mild steel sheet was cut according to the development drawing by using a laser cutting technique. Then, using an arc welding technique, the metal sheet was finally joined to form the shape of column. Figure 4.3 and 4.4 shows the welding and finished column.

Figure: Schematic Process of Welding of Hopper **Figure: Schematic View of Fabricated Column**

Fabrication of Trolley The trolley is a hub to which the Cross travel wheels were placed. At the top of trolley the Bevel gear arrangement is attached to provide the forklift a slewing motion which is important for reducing the turning radius of the forklift. The trolley is made of mild steel sheet of 3mm thickness.

The mild steel sheet is cut according to the development diagram with the help of laser cutting technique. Then the sheet is welded with the help of arc welding machines. Figure 4.5 shows the completely fabricated trolley.

Figure: Fabricated Trolley Initially Bent Long Travel Car

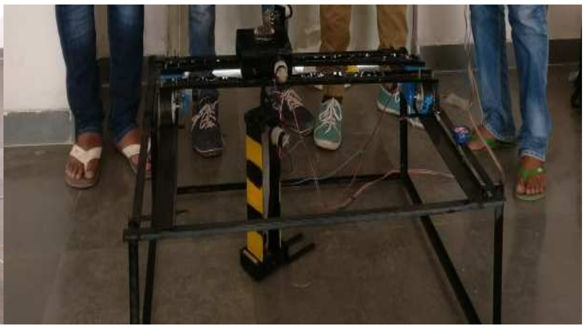
Long Travel Cars

The long travel cars are made by taking 1mm thick galvanized iron sheet. Then the sheet metal is bent to form the shape of the long travel car. Then the bent sheet has drilled holes on both sides of it. The following figure 4.6 shows the initial bent long travel, car and figure 4.7 shows the final long travel car with wheels and motor accommodated to it.

Figure: Final Long Travel Car with Wheels Schematic Process of Welding a Structure

Fabrication of Structure Based on design calculations, a structural frame of dimensions 800 x750 x 38 mm has to be constructed. Then the mild steel L-angles were taken in constructing the structure. Then the L-angles were cut according to the required dimensions by using laser cutting technique. Then these L-angles were welded with the help of an arc welding machine to form the shape of a structure to support the girders and other operating equipment. Figure 4.8 shows the schematic welding of the structure and also figure 4.9 shows the finished structure.

Schematic View of Structure Completely Fabricated Overhead Travelling Cargo Handling Machine

Assembly

All the components, which are individually fabricated are now assembled by means of pre-assembly process on the structure. Figure 4.10 shows the finished machine. The Long travel girders are fixed to the structure and the Cross

travel girders were fixed to the top of long travel cars. The trolley along with the column and fork carrier is placed above the cross travel girders. The electric motors are attached to the wheels of long travel cars and also to the wheels of the trolley. Two 3.5 R. P. M motors were attached to the column in order to rise the carrier along the length of the column. This completes the whole setup which is ready for testing of the machine.

CONCLUSIONS

This project has discussed the design of overhead travelling cargo handling machine and development of a prototype system for material handling such as lifting pallets. The idea of reducing the risk for workers working in the warehouses and in-house pollution paved way for developing this project. All the topics related to this system, i.e., from selection of appropriate components, identifying their functionality, thereby utilization of those components which has reduced the emissions from the exhausts of forklifts. On the other hand, however, we must be practical and realize that the profit-oriented and very much fragmented material handling industry will naturally prefer short term and immediate solution to its shortage in storage problems. The most promising applications are bound to be the risk free Man-Machine interaction innovations that can be economical. These applications will be viewed as a natural extension of present technologies, and will pave the way for fully automated systems in the long run. The following objectives were accomplished during the development of overhead travelling cargo handling machine: Information for developing a product for material handling process was gathered. This includes the study of physical properties of present method, optimum parameters of the process and its working rate.

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